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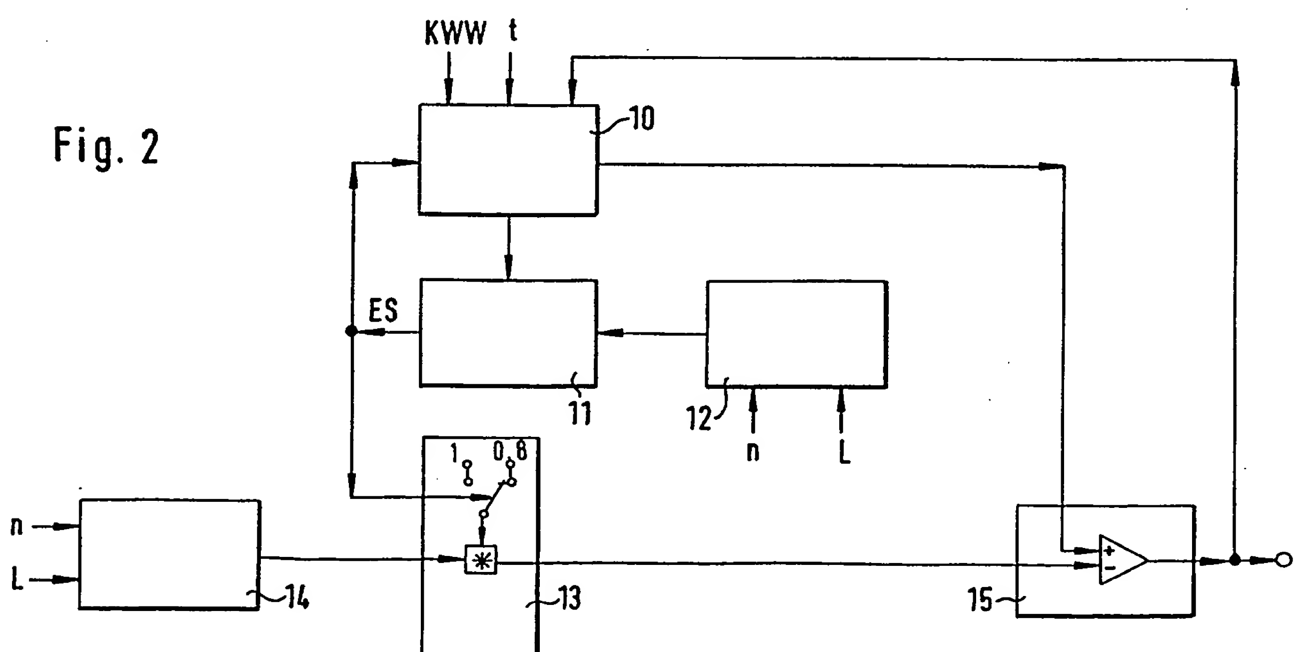
(54) Misfire recognition in an engine

(57) A system for the recognition of multiple cylinder misfiring, and association of misfires with particular cylinders in the case of recognised multiple misfiring, in a multicylinder internal combustion engine comprises means (10) to ascertain rough-running values for individual cylinders and then, from these, values, to form sum terms. From these, in turn, are formed sums which are compared in comparison means (11) with threshold values from a block (12). If at least one sum exceeds the associated threshold value, this indicates the presence of multiple cylinder misfiring. As soon as multiple cylinder misfiring is recognised, the rough-running threshold values are from a further block (14) lowered, in factor selecting means (13), for association of misfires with particular cylinders. The block (10) receives signals of crankshaft angle and timing cycle. The threshold values from block (12) are themselves dependent on engine speed n and load L.

Fig. 2



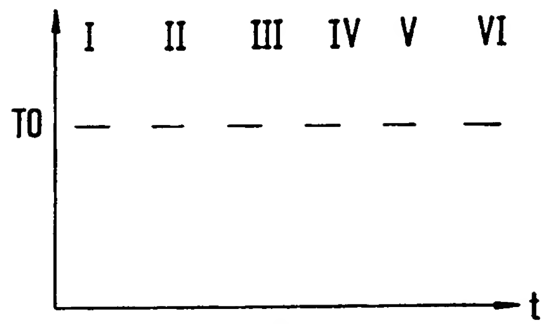


Fig. 1a

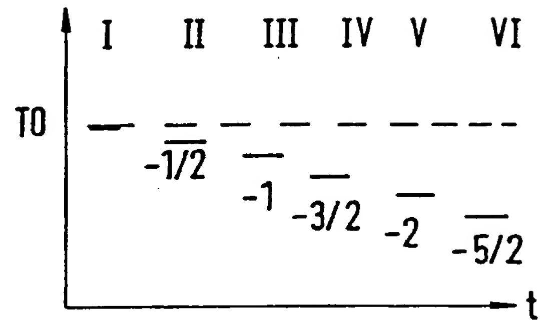


Fig. 1b

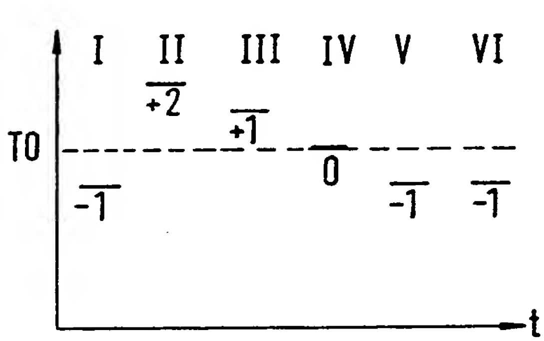


Fig. 1c

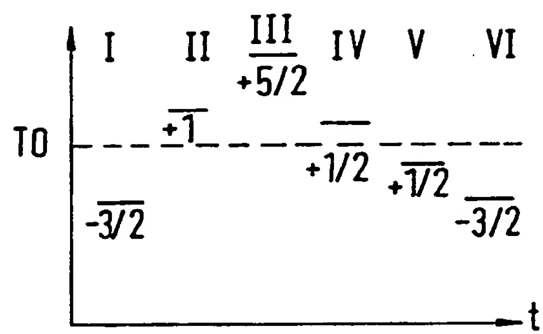


Fig. 1d

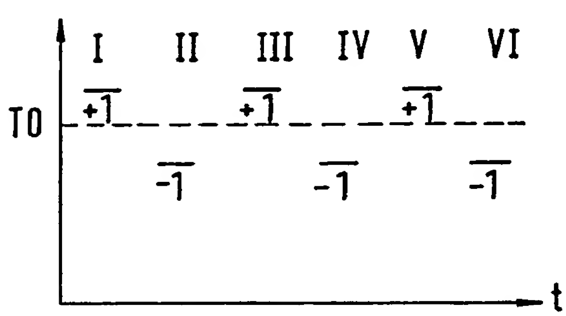


Fig. 1e

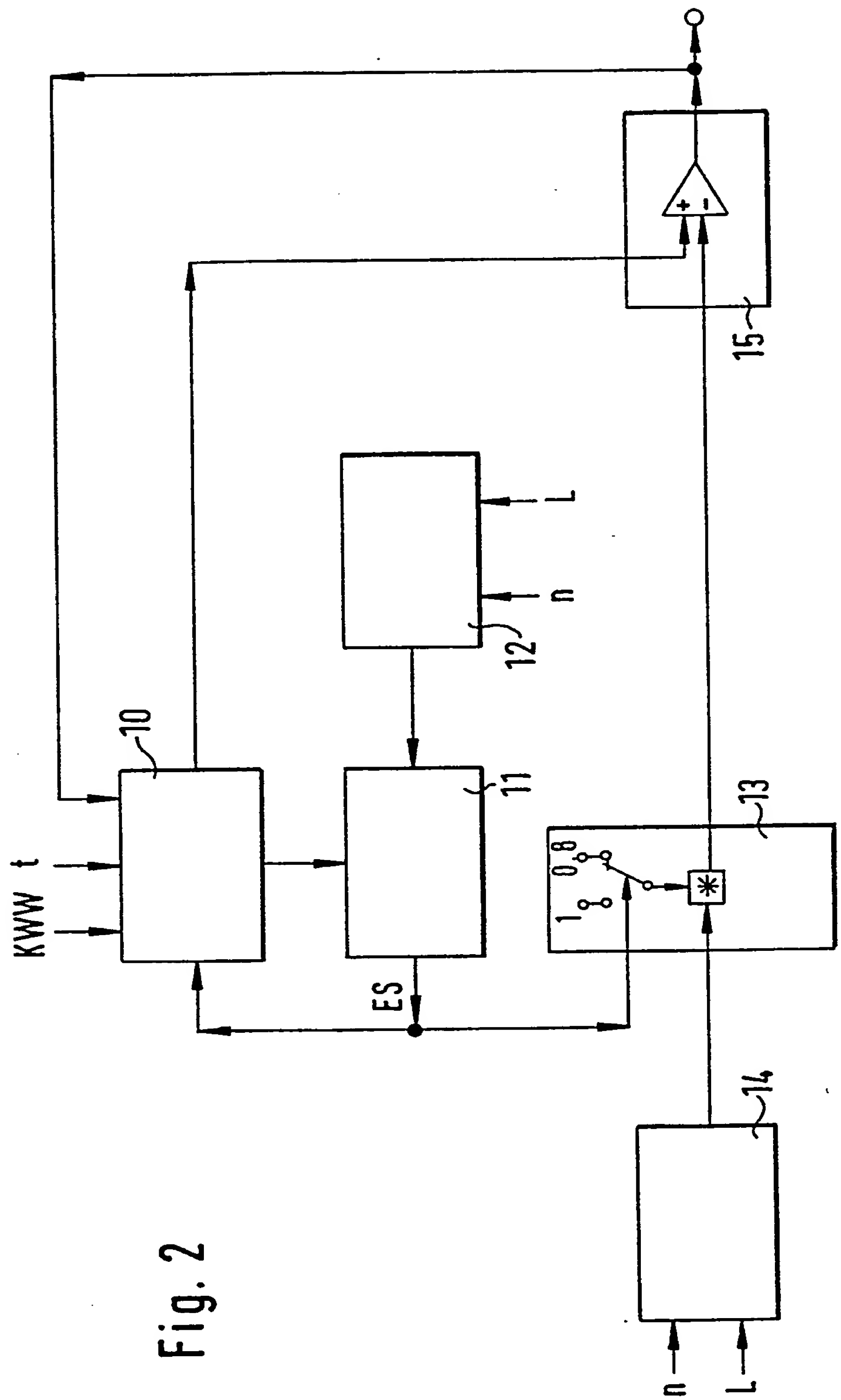
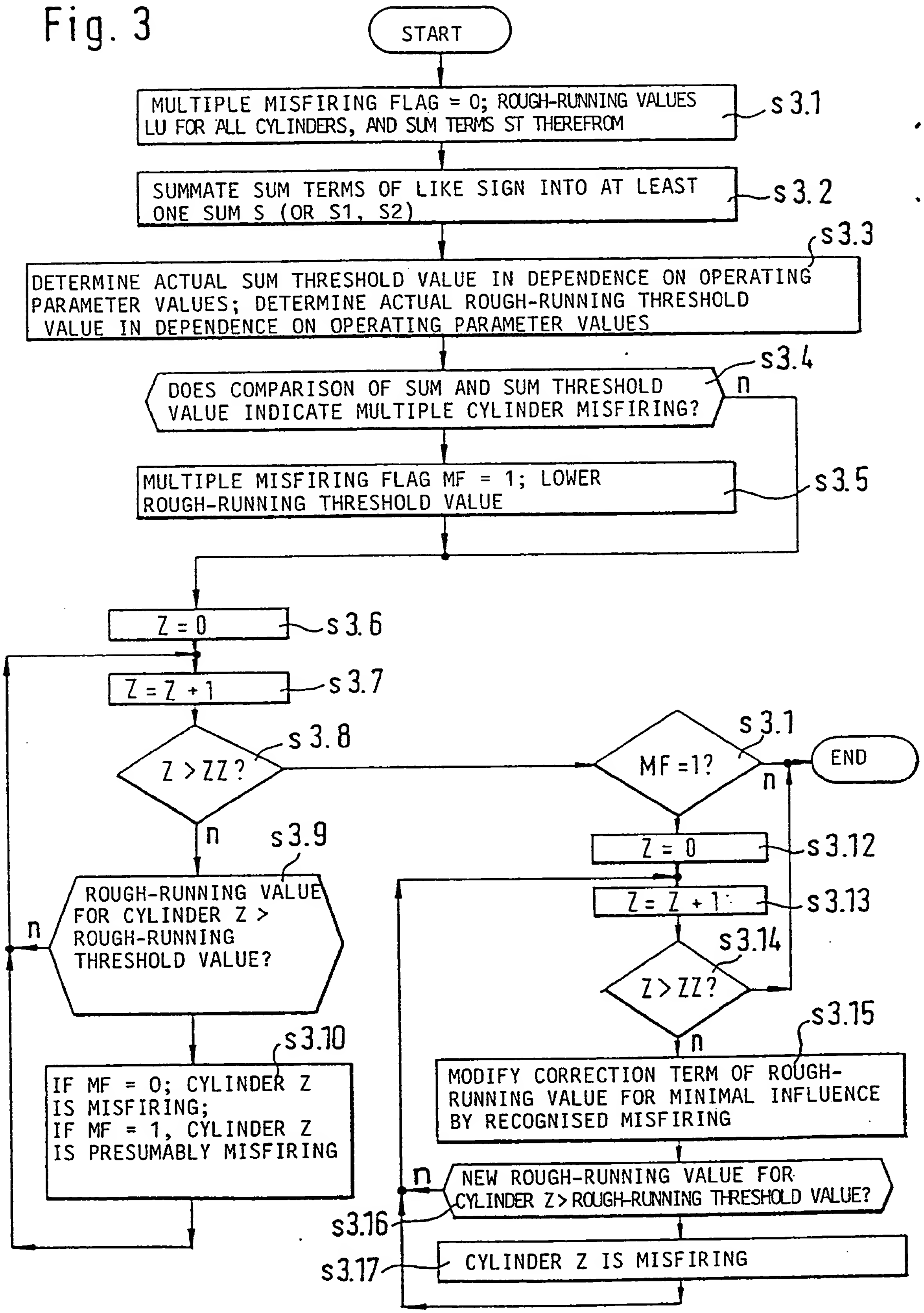


Fig. 2

Fig. 3



START
MULTIPLE MISFIRING FLAG = 0; ROUGH-RUNNING VALUES LU FOR ALL CYLINDERS, AND SUM TERMS ST THEREFROM
s3.1
SUMMATE SUM TERMS OF LIKE SIGN INTO AT LEAST ONE SUM S (OR S1, S2)
s3.2
DETERMINE ACTUAL SUM THRESHOLD VALUE IN DEPENDENCE ON OPERATING PARAMETER VALUES; DETERMINE ACTUAL ROUGH-RUNNING THRESHOLD VALUE IN DEPENDENCE ON OPERATING PARAMETER VALUES
s3.3
DOES COMPARISON OF SUM AND SUM THRESHOLD VALUE INDICATE MULTIPLE CYLINDER MISFIRING?
s3.4
n
MULTIPLE MISFIRING FLAG MF = 1; LOWER ROUGH-RUNNING THRESHOLD VALUE
s3.5
Z = 0
s3.6
Z = Z + 1
s3.7
Z > ZZ?
s3.8
n
ROUGH-RUNNING VALUE FOR CYLINDER Z > ROUGH-RUNNING THRESHOLD VALUE?
s3.9
n
IF MF = 0; CYLINDER Z IS MISFIRING; IF MF = 1, CYLINDER Z IS PRESUMABLY MISFIRING
s3.10
MF = 1?
s3.1
n
END
Z = 0
s3.12
Z = Z + 1
s3.13
Z > ZZ?
s3.14
n
MODIFY CORRECTION TERM OF ROUGH-RUNNING VALUE FOR MINIMAL INFLUENCE BY RECOGNISED MISFIRING
s3.15
NEW ROUGH-RUNNING VALUE FOR CYLINDER Z > ROUGH-RUNNING THRESHOLD VALUE?
n
s3.16
CYLINDER Z IS MISFIRING
s3.17

$$LU(i) = [T(i)-T(i-1)] - [T(i-1)-T(i-2)] \tag{1}$$

$$LU(i) = [T(i)-T(i-1)] - [T(i-3)-T(i-4)] \tag{2}$$

$$LU(i) = [T(i)-T(i-1)] - [T(i-1)-\{T(i-1)+T(i-3)\}/2] \tag{3}$$

$$LU(i) = [T(i)-T(i-1)] - [T(i-1)-T(i-ZZ)]/ZZ \tag{4}$$

$$LU(i) = [T(i)-T(i-1)] - [T(i-1)-T(i-\{ZZ-1\})]/(ZZ-1) \tag{5}$$

$$ST(i) = LU(i) \tag{6}$$

$$ST(i) = LU(i) - LU(i-1) \tag{7}$$

$$ST(i) = LU(i) - [LU(i+1)+LU(i-1)]/2 \tag{8}$$

$$S = \sum_{i=1}^{ZZ} |ST(i)| \tag{9}$$

$$S = c * S\_VOR + (1-c) * |ST(i)| \tag{10}$$

$$S = |LU(i-ZZ)| + |ST(i-ZZ+1)| + \cdots + |ST(i-1)| + |LU(i)| \tag{11}$$

$$S1 = \sum_{i=1}^{ZZ-1} LU(i) \tag{12}$$

$$S2 = \sum_{i=2}^{ZZ} LU(i) \tag{13}$$

$$S = S1 - S2 \tag{14}$$

Fig. 4

MISFIRE RECOGNITION IN AN ENGINE

The present invention relates to a system for recognition of multiple cylinder misfiring in a multicylinder internal combustion engine, that is to say multiple misfires due to several cylinders being affected by misfiring. In practice, combustion will be absent in every, or almost every, combustion cycle in these cylinders.

Numerous methods are known for recognition of combusion misfires in cylinders. Of these, of interest in the following are only the methods which operate with rough-running values, which essentially describe rotational speed fluctuations of the engine. The more strongly the rotational speed fluctuates due to misfiring, the greater, as a rule, is the rough-running value. When the actual rough-running value exceeds a threshold value, which is typically read out from a characteristic field in dependence on actual values of operating parameters, this is a sign of misfires being present in the cylinder concerned.

A survey of different systems for the recognition of combustion misfires is given in DE-A-41 00 528. This survey is referred to for the sake of brevity. It is merely noted here that a rough-running value typically comprises a basic term and a correction term. The basic term is, for example, the difference between the time spans in which a certain angular region is swept by the crankshaft each time in the instantaneous and immediately preceding combustion cycles. If the engine speed is uniform, this difference is zero. Deviations from the value zero occur in the case of misfires, but also in the case of acceleration or deceleration. The correction term serves to provide compensation for disturbing effects such as acceleration and deceleration and is, for example, the difference between the time spans in which the specified

angular region was swept in the last and the penultimate combustion cycles. If a constant acceleration or deceleration without misfires is present, the stated differences forming the basic term and the correction term are equal, in which case the rough-running value results as zero when this value is formed by subtraction of the correction term from the basic term. In order to be able to compensate not only for constant accelerations and decelerations but also for more complicated disturbances as accurately as possible, correction terms are often computed in greater detail, in which case mean value formation is of great advantage. The correction terms can also be multi-membered so as to take several disturbances into consideration.

In spite of the effort expended in computation of rough-running values, erroneous recognitions constantly occur in practice, i.e. either misfires are associated with a correctly operating cylinder or a cylinder with faulty combustion is not recognised as such. These erroneous recognitions occur particularly in the case of multiple misfires.

There is thus a need for a system for recognition, as free of errors as possible, of misfiring cylinders in a multicylinder internal combustion engine.

According to one aspect of the present invention there is provided a system for identifying a misfiring cylinder in a multi-cylinder internal combustion engine, comprising means to determine rough-running values for individual cylinders of the engine, means to determine a respective rough-running threshold value for misfire identification in an individual cylinder in dependence on engine operating parameter values, means responsive to recognition of multiple cylinder misfiring to lower the threshold value relative to determined values to be compared therewith, and means to identify a misfiring cylinder when the determined value for

that cylinder exceeds the respective lowered threshold value.

On the basis of observations and considerations explained more closely further below, it has proved that erroneous recognitions in the case of multiple misfiring are particularly due to the fact that the threshold value, with which the respective actual rough-running value is compared, has not been modified in the case of multiple misfiring. If the threshold value, for example as read out from a values field addressible by way of operating parameter values, is applied to an engine with a single misfiring cylinder, this threshold value must be lowered if it is to be reliably recognised, in the case of multiple misfiring, which cylinders are affected by misfires. It has proved in trials that it is sufficient in practice to lower the threshold value by the same factor each time, for example by 20%, independently of the number of the multiple misfires.

As previously indicated, rough-running values can be formed from a basic term and a correction term, the latter being, for example, the difference between time spans in the last and penultimate combustion cycles. If the individual cylinder recognition has shown that the cylinder which is penultimate in the ignition (firing) sequence is subject to misfiring, it is obvious that the correction term was computed erroneously. In the case of a rough-running value with a basic term and a correction term, therefore, the system preferably operates to so modify the correction term at least for those cylinders for which misfiring has been recognised that the correction term is influenced as little as possible by misfires, and further to ascertain final rough-running values for those cylinders with use of respective modified correction terms and to finally identify misfiring in a cylinder when the final rough-running

value exceeds the lowered threshold value.

Various measures are possible, of which a few are described more closely further below, for modification of the correction term. The optimum variant depends on, in particular, the manner of computation of the correction term.

According to another aspect of the invention there is provided a system for recognition of multiple cylinder misfiring in a multicylinder internal combustion engine, comprising means to determine values indicative of rough-running of individual cylinders of the engine, means to summate a predetermined number of sum terms which are dependent on the determined values and of like sign, and means to recognise multiple cylinder misfiring if at least one sum obtained from summation of the sum terms exceeds a predetermined threshold value.

By way of explanation, in the case of a bank misfire, thus when all cylinders of an engine cylinder bank are misfiring, such as all three cylinders on one side of a V6 engine, combustions and misfires alternate from one cylinder to the other. This means that the rough-running values are of the same amount, but alternately positive and negative. Summation of values with the same sign can take place by, for example, adding up the amounts of the rough-running values or by adding up all positive values on the one hand and all negative values on the other hand, with each sum then being compared with a threshold value or with the difference between the sums being formed and compared with a threshold value.

With such a sum formation it is possible not only to recognise multiple misfires, but also to recognise which cylinders are affected by misfires. This is again explained by the example of a bank misfire. If

it is predetermined that two groups of cylinders, which exactly correspond to the banks, are formed and if the sum values are added up in each group, a particularly high difference between the sums for the two groups must result in the case of a bank misfire. If a correspondingly high threshold is then exceeded, this accordingly indicates not only that multiple misfires are present, but also that it must be a bank misfire. It will be evident which is the misfiring bank from the sign of the difference between the sum values.

If other kinds of collective misfires apart from bank misfires are particularly likely to occur for a particular engine construction, it is advantageous to form two groups of which one contains those cylinders likely to be affected by collective misfiring and the other the remaining cylinders. The further procedure can otherwise be as described for bank misfiring.

Embodiments of the present invention will now be more particularly described by way of example with reference to the accompanying drawings, in which:

Figs. 1a to 1e are diagrams concerning time spans in six successive combustion cycles (I to VI) for the cases (1a) constant engine speed without misfires, (1b) linearly increasing engine speed without misfires, (1c) constant engine speed with a single misfire, (1d) constant engine speed with two successive misfires, and (1e) constant engine speed with a bank misfire;

Fig. 2 is a schematic block diagram of a system embodying the invention;

Fig. 3 is a flow chart illustrating steps in operation of a system embodying the invention; and

Fig. 4 is a chart of equations for rough-running values, sum terms and sums able to be utilised by systems embodying the invention.

Referring now to the drawings, there is explained, with the help of Figs. 1a to 1e, problems which arise during the fixing of threshold values for the recognition of misfires in the cylinders of a multicylinder internal combustion engine. In each of Figs. 1a to 1e, the x-axis denotes time t, whereas the y-axis denotes the time span within which a predetermined angular region is swept by the crankshaft, for example the angular region from -30° before the beginning of a combustion cycle to 30° after the beginning of that cycle for a respective cylinder I to VI. The time span measured for each cylinder is identified by a horizontal bar. In the case of constant engine rotational speed without misfires (Fig. 1a), all time spans have the value T0. The value of T0 is drawn as a dashed reference line in Figs. 1b to 1e.

A rough-running value for, for example, the cylinder IV can be defined by the equation $(T_{IV} - T_{III}) - (T_{III} - T_{II})$. The front bracketed expression represents a basic term for the rough-running value and the rear bracketed expression a correction term. Both terms have the value zero in the case of constant engine speed without misfires and the rough-running value itself is thus zero.

When the engine speed is increased linearly, as illustrated in Fig. 1b, the stated time spans shorten from one cylinder to the next. It is assumed in Fig. 1b that the change from one time span to the next is in each case a shortening by any desired unit. In this case, the basic term

as defined above has the value -1/2, which is also valid for the correction term, so that the rough-running value is again zero.

Fig. 1c concerns the case of a single misfiring cylinder, in this instance the cylinder II. In the case of this cylinder there is a prolongation of the stated time span. A prolongation by two arbitrarily chosen units is assumed. Since the engine speed shall remain constant, a shortening of the stated time span must occur for at least one of the other cylinders. In Fig. 1c, such shortenings are present for the cylinders I, V and VI.

The example of Fig. 1d concerns misfires in two successive cylinders, in this instance cylinders II and III. Prolonged time spans again occur for these cylinders, as well as for cylinder IV, whilst the time spans are shortened for the other cylinders.

Fig. 1e concerns a bank misfire, i.e. a multiple misfire case, in which all cylinders of one bank misfire, in this instance the cylinders I, III and V. The stated time spans are prolonged for these cylinders, whilst they are shortened for the other cylinders.

If it is now assumed that a vehicle with misfiring in one cylinder as shown in Fig. 1c is travelling with a predetermined value of engine speed and load up a slightly rising hill, when two cylinders fail, as shown in Fig. 1d, the same vehicle will presumably be able to travel with the same engine speed and load only on a level road. If an entire bank fails, thus three cylinders as shown in Fig. 1c, the vehicle can maintain the specified engine speed and load only in the case of travel along a slightly downhill stretch of road. It is obvious that if the vehicle is travelling uphill and combustion suddenly fails, the engine is retarded more strongly than when the vehicle is travelling slightly downhill. In

other words, the higher the torque to be exerted by the engine, the greater the engine rotational speed reduction on failure of combustion. The rough-running value thus becomes less with falling torque. If threshold values for comparison with rough-running values are now recorded for different engine speeds and loads on a test bed for an individual cylinder with misfires and entered into a values field, the problem arises that these threshold values are too high for multiple cylinder misfiring, since the torque is, as explained above, smaller in the case of multiple misfires with a predetermined engine speed and load than in the case of misfires in a single cylinder.

The recognition explained above is exploited by a system embodying the invention in such a manner that it lowers the threshold values read out from a field for the comparison with determined instantaneous rough-running values when it is recognised that multiple misfires are present. Alternatively, the threshold values read out from the field could be kept constant in the case of multiple misfires and the determined rough-running values for comparison therewith could be raised.

The system described in the following, however, exploits a further recognition, which is also evident from Fig. 1c to 1e. In particular, although the magnitude of the step from one time span to the next progressively reduces with increasing number of misfires, the sum of the amounts of the steps progressively increases. Thus, a maximum step from -1 to +2 for the single cylinder II with misfires is shown in the example of Fig. 1c, a maximum step from -3/2 to +1 is shown in Fig. 1d with two successive cylinders misfiring, and a maximum step for +1 to -1, and conversely, is shown in Fig. 1e with a bank misfire. The sum of all the differences, however, changes in reverse direction, and is namely a

minimum with the value 6 for Fig. 1c, a maximum with the value 10 for Fig. 1e, and an intermediate value 8 in Fig. 1d. Multiple misfires can thus be recognised by particularly high sum values. In order to keep the influence of acceleration or deceleration small, it is of advantage not to use the differences between two successive time spans directly as sum terms, but to form the sum terms in more complicated manner, which is described more closely further below.

In the block illustration of a system embodying the invention (Fig. 2), a computing block 10 for the computation of the afore-mentioned rough-running values and sums is present. This computing block receives signals KWW relating to the actual crankshaft angle and timing cycle signals t. The block 10 supplies the computed sums to a multiple misfire recognition block 11, to which also sum threshold values from a sum threshold value block 12 are fed. The block 12 preferably has the form of a characteristic field which is addressible by the actual values of engine rotational speed n and engine load L. The computed sums are compared with the actual sum threshold value in the block 11. If a multiple misfire case is recognised on the basis of the comparison, a recognition signal is issued, which fulfils different functions. One function is that it switches over from a multiplying factor of 1 to a multiplying factor of 0.8 in a threshold value-lowering block 13. A rough-running threshold value, read out from a rough-running threshold value block 14, is multiplied by this factor. The block 14 preferably has the form of a characteristic field which is addressible by the actual values of engine speed n and load L. The product resulting from the multiplication of the threshold value and the selected factor is supplied to a comparison block 15, in which rough-running values from the block 10

are compared with the rough-running threshold value modified by the factor. The comparison block 15 issues, for one cylinder after the other, a signal which indicates whether the respective cylinder is subject to misfiring or not. These comparisons take place twice in the case of multiple misfires. It is firstly examined, on the basis of the original rough-running values, which cylinders probably have misfires. When this is ascertained, the correction terms in the rough-running values are so modified that they are as independent as possible of the measurement values from the cylinders presumably affected by misfires. The stated comparisons are then carried out again with the rough-running values thus modified.

If the signal from the block 11 indicates that multiple misfires are not present, the factor of 1 is selected in the block 13 and the comparisons are carried out only once in the block 15 on the basis of the original rough-running values.

The functional sequence, which has just been described, of the components of the system is illustrated in more detail in the flow chart of Fig. 3. Since the blocks of this flow diagram are inscribed in relatively great detail, a description of what is directly evident from the flow chart will be dispensed with. However, examples for the computing of rough-running values and sum terms in step s3.1, the summation of sum terms in step s3.2 and, following directly, the modification of rough-running values in step s3.15, are now explained by reference to Fig. 4.

The equation (1) of Fig. 4 concerns the computation of a rough-running value LU(i) for a cylinder 1 with a basic term and a correction term, as explained above by reference to Figs. 1a to 1e. The basic term

odd-numbered cylinders and a sum S2 for even-numbered cylinders, and the rough-running values are used directly in each sum. These rough-running values have the same sign in each group in the case of a bank misfire, thus are all positive in the one group and all negative in the other group. Due to the summation not taking place in terms of amount, it is ensured that particularly high group sums are obtained only when a bank misfire is actually preent. Such a bank misfire can be reliably ascertained when at least one of the group sums lies above a sum threshold value. The result is even more reliable if, according to equation (14), the difference between the two group sums is formed and the value thus obtained is compared with a respective threshold value.

The example of a system embodying the invention according to Figs. 2 and 3 uses three principles which are applicable individually or in combinations. The first principle is that of the multiple misfire recognition through sum formation. The second principle is that of relative lowering of the threshold value for rough-running values in the case of multiple misfires. The third principle is that of modification of rough-running values in the case of multiple misfires in such a manner that the correction term is as independent as possible of misfires for the computation of a respective rough-running value.

In the case of the embodiment relating to the second mentioned principle, it was presumed that rough-running threshold values are predetermined for misfires in only a single cylinder. In this case, the respective rough-running threshold value is to be lowered in the case of multiple misfires. However, if rough-running threshold values are to be predetermined for multiple misfires, these threshold values would have to be increased in the case of the absence of multiple misfires.

A general misfire recognition method with a sum according to one of the equations (9) to (11) is explained in the flow chart of Fig. 3. However, when group misfires represent the most probable kind of multiple misfire in an engine, it can be expedient to initially carry out a group misfire recognition, for example the block misfire recognition according to the equations (12) to (14). If the examination shows that misfiring is actually present, the affected cylinders are immediately known. The performance of a more complicated multiple misfire recognition procedure, with subsequent ascertaining of the cylinders actually affected, can thus be dispensed with.

CLAIMS

1. A system for recognition of multiple cylinder misfiring in a multicylinder internal combustion engine, comprising means to determine values indicative of rough-running of individual cylinders of the engine, means to summate a predetermined number of sum terms which are dependent on the determined values and of like sign, and means to recognise multiple cylinder misfiring if at least one sum obtained from summation of the sum terms exceeds a predetermined threshold value.

2. A system as claimed in claim 1, wherein each sum term is a respective such determined value.

3. A system as claimed in claim 1, wherein the sum term for each cylinder is the difference between the determined values for the adjacent cylinders in the cylinder sequence.

4. A system as claimed in claim 1, wherein the sum term for each cylinder is the difference between the determined value for that cylinder and the mean of the determined values for the adjacent cylinders in the cylinder sequence.

5. A system as claimed in any one of the preceding claims, the means to summate being arranged to add up the sum terms in magnitude.

6. A system as claimed in any one of claims 1 to 5, the means to summate being arranged to form the sum of the sum terms for a first plurality of cylinders predetermined to have sum terms of positive sign for a

particular type of multiple cylinder misfiring and to form the sum of the sum terms for a second plurality of cylinders predetermined to have sum terms of negative sign for that type of misfiring.

7. A system as claimed in claim 6, the means to recognise being arranged to form the difference of the two formed sums, to recognise multiple cylinder misfiring of said predetermined type if the formed difference exceeds a respective threshold value, and to associate the misfiring with the cylinders of one of said two pluralities in dependence on the sign.

8. A system as claimed in claim 1, comprising means to determine the threshold value in dependence on operating parameters of the engine.

9. A system for identifying a misfiring cylinder in a multi-cylinder internal combustion engine, comprising means to determine rough-running values for individual cylinders of the engine, means to determine a respective rough-running threshold value for misfire identification in an individual cylinder in dependence on engine operating parameter values, means responsive to recognition of multiple cylinder misfiring to lower the threshold value relative to determined values to be compared therewith, and means to identify a misfiring cylinder when the determined value for that cylinder exceeds the respective lowered threshold value.

10. A system as claimed in claim 9, the means to lower being arranged to lower the threshold value by the same factor on each recognition of multiple cylinder misfiring irrespective of the number of misfiring cylinders.

11. A system as claimed in claim 9 or claim 10, wherein each of the determined rough-running values is defined by an equation with a basic term and a correction term and the system comprises means to so modify the correction terms of the determined values for the cylinders recognised to be subject to misfiring that the misfires have the smallest possible influence on the correction term and means to determine final rough-running values for each of those cylinders from the respective equation with the modified correction term, the means to identify being arranged to identify a misfiring cylinder if the determined final value for that cylinder exceeds the respective lowered threshold value.

12. A system as claimed in claim 11, wherein each correction term comprises measured values and the system comprises means to replace each measured value in the correction term of the determined value for a cylinder recognised to be subject to misfiring by the respective mean value of the corresponding measured values associated with the closest cylinders, in the cylinder sequence, that are free of misfiring.

13. A system as claimed in claim 11, wherein each correction term comprises measured values and the system comprises means to so compute the correction term values that these exclude measured values from any cylinder recognised to be subject to misfiring.

14. A system substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977
Ex iner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

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(ii) Int Cl (Edition 5) F02B 77/08
G01M 15/00

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

M G CLARKE

Date of Search

24 AUGUST 1992

Documents considered relevant following a search in respect of claims 1 TO 14

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A P	GB 2250347 A (ROBERT BOSCH GMBH) Whole document	1
A P	GB 2249839 A (FUJI JUKOGYO KK) Whole document	1
A P	GB 2247319 A (FORD MOTOR CO LTD) Whole document	1

Category	Identity of document and relevant passages	Relevant to claim(s)

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